# A Framework for Selecting and Analyzing Indicators of Sustainable intensification

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Contents

[A Guidebook for Selecting and Analyzing Indicators of Sustainable intensification 1](#_Toc466876815)

[1. What is Sustainable Intensification? 2](#_Toc466876816)

[2. The Sustainable Intensification Indicator Framework 2](#_Toc466876817)

[3. Approach used to refine sustainability indicators 4](#_Toc466876818)

[4. How to use the SI indicator framework 6](#_Toc466876819)

[5. Presenting indicator output 9](#_Toc466876820)

[6. Proxy Indicators 13](#_Toc466876821)

[7. Productivity Domain 14](#_Toc466876822)

[8. Economic Domain 18](#_Toc466876823)

[9. Environment Domain 22](#_Toc466876824)

[10. Human Condition Domain 30](#_Toc466876825)

[11. Social Domain 34](#_Toc466876826)

[References 39](#_Toc466876827)

[Appendix 1: Exercise on tradeoffs and synergies for sustainable agricultural intensification 44](#_Toc466876828)

**Sustainable intensification indicators framework**

# 1. What is Sustainable Intensification?

Sustainable Intensification focuses on improving the efficient use of resources for agriculture, with the goal of producing more food on the same amount of land but with reduced negative environmental or social impacts.  The term "sustainable intensification" originated in the 1990s in the context of how to achieve improved yields over the long-term in fragile environments of Africa (Pretty, 1997; Reardon et al., 1995).  Intensification has the potential to reduce pressure from population growth on the conversion of natural lands to agriculture (Cook et al., 2015).  Unfortunately, sustainable intensification has become somewhat of a buzzword that is often used to describe any type of agricultural intensification that may have any potential environmental benefit (Godfray, 2015). Sustainable agricultural intensification should not be viewed as a particular set of practices but instead be used as a conceptual framework for guiding discussions on achieving balanced outcomes from intensification (Garnett and Godfray, 2012). Thus, there can be alternative pathways to sustainable agricultural intensification which will vary by location and scale, based on the agro-ecological zone, farming system, cultural preferences of farmers, institutions and policies, among other factors. Each of these pathways will have a different set or levels of environment and socioeconomic tradeoffs and/or synergies.

Research on sustainable intensification (SI) needs to be interdisciplinary, drawing upon the theories and methods of the biophysical and social sciences. Recent SI work has a major emphasis on crop management strategies that can reverse land degradation and reduce yield variability despite climatic changes (Dahlin and Rusinamhodzi, 2014). Much of this SI research focuses on the environmental aspects of sustainability using biological and ecological principles to improve the ecosystem services of a given farming system and to reduce the environmental problems associated with it (Petersen and Snapp, 2015).

However, production practices that are environmentally sound and economically profitable may have complex social dimensions that affect sustainability. SI is often presented as a solution to food insecurity and malnutrition. However, increased agricultural productivity does not automatically reduce food insecurity and malnutrition. Achieving those goals requires fair distribution of the benefits from that increased production. For this reason, SI interventions need to explicitly consider issues of equity, poverty alleviation and gender empowerment (Loos et al., 2014). Ignoring these aspects can threaten the sustainability of enhanced production. For example, if food insecurity is ignored, farmers may have no choice but to sell off productive assets (such as plows or oxen) to meet their basic needs, thus compromising their ability to continue managing their farms.

# 2. The Sustainable Intensification Indicator Framework

*a. Purpose of the SI indicator framework*

Numerous indicators have been used and recommended for assessing sustainable agricultural intensification (Lopez-Ridaura et al. 2005; Speelman et al, 2007; ISPC, 2014; Smith et al., 2016). However, a limited number of studies (Smith et al., 2016) have explicitly explored the gaps and needs scientists face in using sustainability indicators in research for development projects. The sustainable intensification indicators framework described in this document aims to provide a synthesized list of indicators and metrics. The indicators and guidelines presented in this document should not be seen as the only way to assess SI. Instead the goal is to provide a common framework that can guide research on SI and facilitate cross-program learning and assessment on the factors that lead to successfully working towards sustainable intensification.

The framework is primarily intended to guide agricultural scientists working in research for development projects but is flexible and can be used by scientists interested in sustainable intensification more broadly. Scientist working in research for development projects may use this the framework for a ‘pre-adoption’ assessment of the potential sustainability of their intervention. This ‘pre-adoption’ assessment provides important information for use in the adoption phase (or roll out) phase of the technology. The indicators and metrics are categorized into five domains (productivity, economic, environmental, social and human condition) each having four scales (field, farm, households, and landscape). The framework of indicators and metrics provided below includes both ‘gold standard’ approaches, as well as, simplified methods and metrics as options that may be more feasible to use considering the spatial, temporal and cost limitations. From these tables of indicators researchers and stakeholders can select those most relevant to their programs.

The first type of assessment that can be carried out with this indicator framework is to analyze the sustainability of intensification interventions by collecting data for the most relevant indicators for the intervention to compare an SI intervention with the status quo. Data on SI indicators can be presented through visualization techniques such as radar charts to compare performance of innovations or interventions. Instead of combining indicators into an index (where important details become obscured) the results for each indicator can be presented. This allows communities, scientists, implementation partners and policy makers to objectively evaluate the research results based on the importance they assign to each indicator. Different stakeholder groups may have different priorities regarding sustainability related goals (e.g. biodiversity conservation, agricultural production, food security, and gender equity). [examples from literature and Snapp et al – forthcoming]. Where long-term data is available the SI indicators framework can also be used to quantify trajectories of sustainable intensification by comparing indicators from all domains across time. [examples include MVP analysis (in prep) and Ollenburger et al. 2016]

A second type of assessment is to use the lists of indicators by domain to identify potential tradeoffs and synergies from an SI intervention. In the exercise provided in Appendix 1 researchers can consider how the various indicators listed under each domain might be affected positively or negatively by an intervention that they are investigating or planning to research. This exercise provides a structured means of considering the broader farming and livelihood systems. This type of qualitative assessment should be informed by the scientific literature as well as by discussions with farmers, fellow researchers, NGOs or other stakeholders about the potential direct and indirect effects of a SI intervention. By using this exercise, researchers could anticipate potential synergies and tradeoffs and minimize unintended negative consequences by mitigating them through the research design. The exercise can also be used during the process of selecting indicators for the type of data collection and assessment described in the previous paragraph.

The SI indicators framework could also be used to guide monitoring and evaluation (M&E) efforts in development projects. All of the key concepts and methods for measuring or estimating the indicators are presented in the framework. Several considerations would be needed to effectively scale up or aggregate plot and household level indicators to assess the project-level effect (such as at the village, watershed or sub-district level). Nevertheless, the same process for selecting the most relevant indicators and reflecting on synergies and tradeoffs could be applied to M&E for development projects.

*b. Five domains of Sustainable Intensification*

Various dimensions of sustainability emerged from extensive discussions with scientists and a review of the literature. These dimensions were classified into five domains including productivity, economic, environment, human condition and social. The assignment and choice of domains may have some level of ambiguity as some indicators have characteristics attributed to more than one domain. For our purpose, the domains are described and organized as follows:

**Productivity**: Increasing productivity is the essential characteristic of intensification, with the goal of increasing output per unit input per unit time (season or year). Following the SI literature, this domain focuses on land as a critical input, and the consequences both positive and negative to land degradation and habitat loss. Other inputs associated with intensification (such as labor, water quality, fertilizer and capital) are captured in the economic domain.

**Economic**: This domain focuses on issues directly related to the profitability of agricultural activities and returns to factors of production. In addition to profitability, this domain includes indicators related to the productivity of inputs apart from land including water, nutrients, labor and capital. Furthermore, indicators likely to affect the probability of investment in enhancing productivity (market participation) are included.

**Environment**: This domain focuses on the natural resource base supporting agriculture (e.g. soil, water), the environmental services directly affected by agricultural practices (e.g. habitat, water holding capacity) and the level of pollution coming from agriculture (pesticides, greenhouse gases).

**Human condition**: This domain contains indicators that pertain largely to the individual or household, including nutrition status, food security, and capacity to learn and adapt. These indicators affect an individual and do not require social interaction or interpersonal relationships. While these concepts are dependent on social interactions (such as within the household or community), they are distinct from those in the social domain which directly focus on inter-personal relationships.

**Social:** This domain focuses on social interactions: equitable relationships across gender within the household, equitable relationships across social groups in a community or landscape, the level of collective action and the ability to resolve conflicts related to agriculture and natural resource management.

*c. Scales of analysis*

Measuring indicators to assess sustainable intensification typically requires observing parameters at a given scale and determines the unit of analysis, sampling framework, and protocols to be used. This framework includes four scales of analysis – plot level, farm level, household level and the “landscape or administrative unit”. The landscape or administrative unit scale could be defined as community, watershed, district, province or even the nation as a whole. Observing only one scale can be useful for specific analyses but it is important to realize that by ignoring lower or higher scales the analysis may not detect tradeoffs at scales other than the scale of interest. Also, focusing on only one scale fails to consider important interactions across scales.

# 3. Approach used to refine sustainability indicators

To develop a flexible framework, we explored the literature and interacted with scientist to obtain a list of critical indicators and then analyzed them for their precision and their easiness to measure. We also carried out field visits to interact with scientists and stakeholders (farmers and project partners) to obtain insight in the process of stakeholder engagement, data collection, indicator generation, and perception by participants in the process.

A suite of indicators has been proposed and included in the framework from our visits and interactions with scientist that include:

* + Africa RISING meeting with steering committee members
  + Africa RISING Project in Mali and Millennium Villages Project in Mali.
  + Africa RISING project sites in Ethiopia
  + Interaction with scientist at the annual meeting for the sustainable intensification innovation lab (SIIL)
  + CIALCA project in Rwanda
  + An on-line survey of SI researchers – June 2016
  + AfricaRISING ESA Phase 1 Legacy meeting – Tanzania, July 2016
  + Africa RISING ESA Phase 2 planning meeting – Malawi, October 2016

This process has identified data and indicator gaps in the framework but also us data collected in various projects. In situations where data gaps exist, we are proposing data collection methods to fill this gap. Where new indicators are proposed, we plan to present those indicators to experts to provide information on their relevance and measurability. A similar approach has been used by earlier studies (Zurek et al., 2015; Taylor et al, 1993; Van der Werf and Zimmer 1998) to refine indicators in situations where no other possibility of validation exists (i.e. a new indicator is proposed but with no data to estimate it).

**Table 1.** Commonly measured indicators used by SI researchers who participated in an on-line survey 1

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Productivity** | **Economic** | **Environment** | **Human Condition** | **Social** |
| Yield (75%) | Profitability (59%) | Soil Carbon (34%) | Production of nutritious foods (25%) | Gendered rating of technology (43%) |
| Yield variability (50%) | Labor requirements (52%) | Crop water availability (30%) | Capacity to experiment (23%) | Gender equity impact (27%) |
| Crop residue production (45%) | Input use efficiency (48%) | Nutrient Partial Balance (27%) | Dietary diversity (18%) | Conflicts over resources (11%) |
| Cropping Intensity (35%) | Market Participation (34%) | Soil acidity (27%) | Nutrition awareness (16%) | Equity (youth, ethnic, etc.) (9%) |
| Fodder production (32%) | Market orientation (30%) | Vegetative cover (27%) | Consumption - Food access (16%) | Social cohesion (9%) |
| Animal Production (16%) | Variability of profitability (27%) | Erosion (18%) | Food availability – production (14%) |  |

Notes: 1 The number in parentheses indicates the percentage of the 44 respondents who measure that indicator

**Figure 1:** Indicators of sustainable intensification, ranked by average level of agreement (3 = strongly agree and -3 = strongly disagree).

# 4. How to use the SI indicator framework

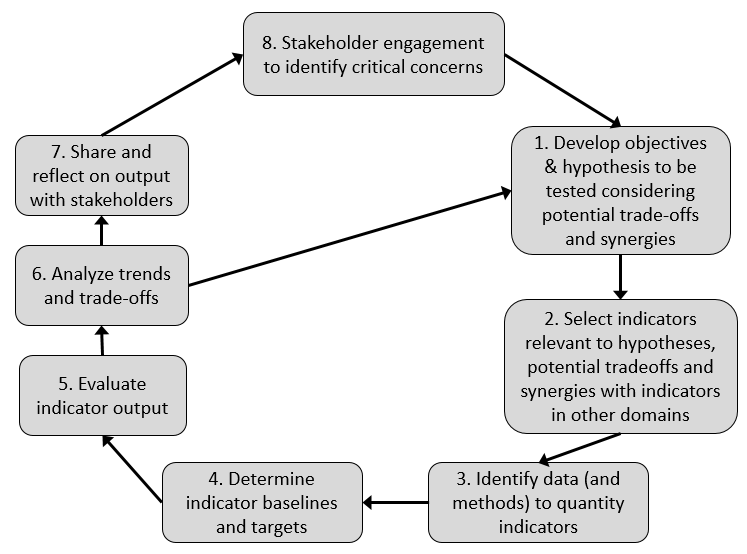
The SI assessment framework aims to be realistic for donor investment and practitioners’ needs by being adaptable to specific contexts and by providing a range of measures for any given indicator: from the gold standard to feasible proxies that are less resource demanding.

a. Process for using the SI indicators

The following steps can be followed for using the SI indicator framework:

1. Engage with stakeholders/consider project objectives and research questions to identify critical concerns. Develop objectives and hypothesis to be tested considering potential tradeoffs and synergies for possible interventions
2. Select indicators from each domain that are relevant or appropriate to the intervention being tested, or the on-farm trajectories being evaluated. Consider also the context, and which indicators are appropriate to the scale of the project and inference zones.
3. Decide how to measure each indicator based on the overall human and financial resources available for data collection and analysis and the expected importance of each indicator in each context (priority indicators). The methods are listed in the right-hand column of each table and are linked to the indicators in each row with superscript numbers. Decide how to operationalize each measure, including sample size and sampling strategy
4. Consider indicator baseline values, thresholds and targets, in the context of the project objectives
5. Collect data and evaluate indicator output, at appropriate scales
6. Analyze and interpret results including trends and tradeoffs
7. Communicate results to the various stakeholders using appropriate techniques for each of those groups.
8. Iteratively engage with stakeholders to consider findings, revaluate critical concerns and ways forward

The results of the analysis and the critical reflection on the implications of those results by stakeholders will often lead to new questions, concerns or adaptations to interventions and another round of selecting indicators (Figure 2).



**Figure 2.** Illustration of process of selecting indicators and presenting the output to stakeholders. (Adapted from Kline, K. 2014 and Stoorvogel et al. 2004).

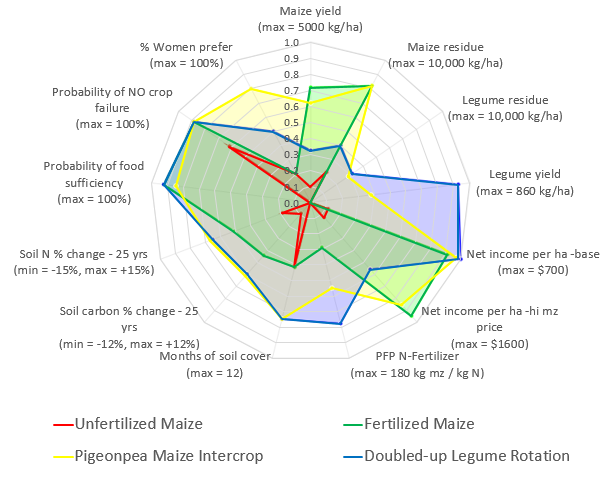
b. Summary of case study applying SI indicator framework in Malawi

A case study of application of the SI indicator is available, based on the USAID-supported Africa RISING project experience in central Malawi (Snapp et al., in preparation). In brief, a participatory action research approach was undertaken to evaluate sustainable intensification trajectories for key household types (Chikowo et al., manuscript submitted ). Based on literature review and stakeholder engagement, research hypotheses were developed, related to the following overall question: can enhanced legume crop diversification increase farming system productivity, profitability, and the environmental sustainability of maize-based cropping? Does this vary with household characteristics and within household? Through an iterative action research process, including a mother-baby trial design and systematic implementation of panel surveys, research questions were developed and refined. Further information of the current status and research directions can be found at this website:

<http://globalchangescience.org/eastafricanode>

To assess sustainability, and consider synergies and tradeoffs within a maize-based system that is associated with increasing legume cover, and diversity of legume functional type, we considered SI indicators in each of the domains. For productivity we relied on cropping system trial data and modeled NPP and yield data associated with maize and grain legumes, to expand the range of weather conditions under consideration and thus the inference zone. For economic indicators we considered profitability based on two scenarios and above productivity values. Environmental domain indicators relied largely on modeled values, and extent and diversity of legume cover based on technology attributes (e.g., pigeonpea-based interventions had greater duration of C and N fixation, due to the nature of pigeonpea growth characteristics, see Snapp et al., 2010). Human condition and social were primarily based on modeled food supply relative to demand of typical households, and farmer participatory rating of technologies and experimentation underway with farmers. See figure 3 where SI indicators are presented for Golomoti, a lakeshore location, a relatively marginal site.

**Figure 3:** Comparison of maize and maize/legume technologies in Golomoti, Malawi across all 5 domains utilizing data from Africa RISING trials, surveys and crop models (adapted from Snapp et al in preparation).



The figure 3 illustrates that maize-pigeonpea and doubled up legumes, two diversified technologies, when compared to continuous maize have many features associated with greater sustainability. Note the diversity of crops produced, including high-nutrient value pigeonpea and other grain legumes, and the extended cover and nitrogen fixation associated with these technologies, which was associated with higher soil N and C accrual than either sole maize system. This is suggestive of greater natural resource base amelioration associated with legume diversification, as hypothesized. However, a challenge emerged in terms of maize production on an annualized basis, which is a very important for food security in this environment: this was only high for fertilized maize. Lack of fertilizer, and high legume integration systems were both associated with modest annualized maize yields, although the doubled-up legume system with judicious fertilizer had high maize yields in that phase of the rotation so for farmers with sufficient land size, this may be a feasible option and a profitable one (Figure 3). One assumption that was highlighted as well, is that legume residues are utilized in a sustainable manner, and this requires more detailed follow up studies.

c. Summary of case study applying SI indicator framework in Tanzania

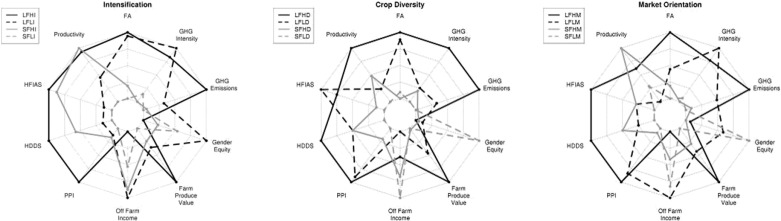
The SI indicator framework may be used to assess whether an objective of a given project is achieved using a set of indicators as an assessment criterion. In a case study in Tanzania, the households in Mbola one of the objectives was to improve food security of the households. This was a data driven approach to indicator selection to assess the performance of the household given the objective. At baseline, (2006/2007) it was reported that households were experiencing incidents of food insecurity in 6 months in a year. Improved maize production with use of fertilizer and improved seeds was used as an intervention to improve food security. Soil management was a sub-objective plus improving incomes from agricultural production. The graph provides an assessment on the performance of the household across indicators such as use of soil management practices, potential food availability, market participation in the cereal market, diversification of food production; across households by sex of household head. In year 3 there was an observed improvement in food security with a reported 1.5 months of insufficient food. Female households had less incidents of food insecurity but this difference was not significantly different from male headed households. There was a concentration on maize production by female headed households who allocated more of their land to maize and had a higher market participation.

**Figure 4:** Comparison of female headed and male headed households regarding maize production and food security in Mbola, Tanzania from 225 households in the year 2009.

# 5. Presenting indicator output

Presenting multiple sustainability indicators to an audience is complex and needs to ensure that relative changes among indicators are captured. There is debate on the optimal number of indicators that can be present on a given visual aid to prevent information over load (Miettinen, 2014) but also ensure that there is a relationship between the indicators that can portray relative differences. In addition, if temporal aspects are being presented, this requires an illustration of change over time of given indicators and the how sustainability may be assessed relative to a given reference level. Similarly, if the impact of context is being considered, an illustration of indicator performance for different contexts needs to be presented. A number of studies have used various methods to present indicator output results to examine trade-offs and or relative changes using bi-plot, bar charts, and matrices. One of the most widely used approaches is variously called radar charts, spidergrams, star-plots and petal diagrams (van Wijk et al, 2016; Zurek et al, 2015; Snapp et al., 2010). Radar charts and petal diagrams can be used to visualize simultaneously a large number of studies or locations, if detail is minimized (Droppelmann et al., 2016)

Indicator output presentation may also require setting and presenting thresholds below and above which a target indicator may be ‘red- flagged for either policy or technological intervention. Zurek et al. (2015) propose use of a traffic light system to indicate whether a given indicator is below of above a critical threshold). In addition, farm typologies can be used to compare performance across given level of intensification. Hammond et al. (2016) present farm performance in Tanzania categorizing farms by size (ha) and intensification level (nitrous oxide emissions) (see Figure 3). In situations with limited data, models have been used to examine trade-off and synergies using bio-economic models, like FarmDESIGN (Groot et al., 2012). This modelling work is currently being done in the CIALCA project in Rwanda but for this purpose we present an example of visual output from earlier work by Groot et al. (2012). The output indicates the farms initial endowment (red dot) and the blue dots indicate scenarios that outperform the original endowment (Figure 3 bottom panel) (Groot et. al., 2012; Kanter et al., (2016). Below we present a few examples that one may draw upon in visualizing the output from the SI framework.



“Farm performance scores for large and small farm types (LF and SF), practicing high and low farm intensification (HI and LI), crop diversification (HD and LD) and market orientation (HM and LM) for Trifinio, Central America. Abbreviations: FA is Food Availability, HFIAS is the Household Food Insecurity Access Scale, HDDS is the Household Diet Diversity Score, PPI is Progress out of Poverty Index.” Source: Hammond et al., 2016.



The red dot represents the original farming system, the green dots present the pareto optimal solutions, and the blue dot, the solutions that outperform the original in all objectives.

Source: Groot et al., 2012

**Figure 5.** Visualization methods for presenting multiple indicator values.

# 6. Proxy Indicators

Proxy indicators are those used when data or information is not observed directly (Riley, 2001). Proxy indicators are used in situations where no direct measurements exist or the cost of direct measurement is too high. An example is that ownership of assets such as car, tin roof, or television may be used to estimate income levels where there is no reliable data on household income, such as from a detailed survey. A similar example is the estimation of nitrous oxide emissions in situations where only information on nitrogen use is available. A recommendation is to estimate that 1% of nitrogen used is emitted as nitrous oxide emissions (IPCC, 2007), though recent field work is showing this may be an overestimate for many areas in the tropics. There is continuing work to determine and document available indicators from direct measurements, modelled output, and remote sensing. In the process of evaluating potential proxies, a question that scientists at IITA have brought up that is important to consider: How can we link agricultural practices to an indicator for sustainability assessment? This is a question for future research that we hope that on-going research might fill this gap. In cases where cost is a limiting factor in data collection for indicator assessment, answering this question will be vital for parsimonious evaluation of technologies.

# Indicators by domain and scale

In the next section, we present tables of selected indicators for each domain across scales that are important for consideration by researchers working in research for development projects. Researchers are not limited to the use of only the listed indicators, but those in the tables provide an initial set of those mostly likely to be important for assessing sustainability of interventions, based on feedback from researchers working on sustainable intensification.

The tables include the methods that can be used for data collection to generate the indicator values (last column to the right of each domain table). A brief discussion of each indicator, units of analysis, and method used to calculate that indicator are provided after the table of indicator by domain. The next section has the indicators listed by domain as follows: productivity, economics, environmental, human condition, and social domain.

# 7. Productivity Domain (Note: The superscript letters (a,b,c) after each metric refer to the measurement methods in the right-hand column)

| PRODUCTIVITY DOMAIN | | | | | |
| --- | --- | --- | --- | --- | --- |
| Indicator | **Field/plot level metrics** | **Farm level metrics** | **Household level metrics** | **Community/ Landscape + metrics** | **Measurement method** |
| Crop productivity | Yield (kg/ha/season) a,b,c(including tree product/area under crown)  Rating of yield d | Yield (kg/ha/season) a,b,c |  | Net primary productivity (NPP)  (kg biomass / ha / yr) e | a Yield measurements  b Recall survey  c Crop models  d Farmer evaluation  e Remote sensing |
| Crop residue productivity | Residue production (kg/ha/season) a,b,c  Rating of residue production d | Residue production (kg/ha/season) a,b,c |  | Net primary productivity (NPP)  (kg biomass / ha / yr) e | Same as for Yield |
| Animal productivity | Animal products and by-products (amount / animal / year)  a,b  Rating of animal productivity c | Animal productivity per unit land (product / ha / yr)  a,b  Herd composition | Animal productivity per household (product / hh / yr)  a,b | Net commercial offtake (product / ha / yr) a | a Recall survey  b Production measurements  c Farmer evaluation |
| Variability of production | Coefficient of variability a  Probability of low productivity a | Coefficient of variability a  Probability of low productivity a | Rating of variability b  Rating of production risk b | Variability of NPP c | a Productivity over time  b Farmer evaluation  c Remote sensing |
| Input use efficiency | Product per input a,b |  |  |  | a Survey and productivity measures  b Models |
| Yield gap | Yield gap (kg/ha/season) | Yield gap (kg/ha/season) |  | Yield gap (kg/ha/season) | Same as Yield |
| Cropping intensity | # of cropping seasons per year a |  |  | #of cropping seasons per year | a Recall survey |

**Description of Productivity Indicators**

**Crop productivity**

Crop productivity is a measure of the total sum of annual plant production, which is also known as net primary productivity. Crop productivity can be partitioned by tissue type (grain, leaves, stems, etc.) based on how the plant is used. The unused portions of crops are often referred to as crop residues, which is the next indicator.

Yield

Yield is a measure of crop production for a given land area, generally measured at the field scale. Yield typically focuses on a limited portion of the plant, such as the grain for row crops. However, in many cases farmers uses nearly all parts of the plant for various purposes. For this reason, we suggest taking into consideration all plant parts used by farmers, remembering that stover left if the field is often consumed by livestock. In many cases, it may be reasonable to focus on grain yield and stover. The portion left in the field and not consumed by livestock plays an important role in nutrient cycling and this is measured in the next indicator, crop residues. Methods for measuring yield include yields cuts, farmer estimates of harvest for measured fields, and crop modeling.

Farmer rating of yield

In cases where farmers have tried a new technology but on-farm yield measurements and detailed surveys are not available, it is possible to obtain farmers’ qualitative evaluations of yields, for example asking them to rank or rate yields for various varieties or management practices, thus making inferences to a particular intervention.

Net primary productivity

Remote sensing can be used to detect optically measured vegetation indices (typically using green (G), red (R) and near infrared (NIR) wavelength bands) from a landscape. One well known index is the Normalized Difference Vegetation Index (NDVI), which can be used to estimate crop production through Net Primary Productivity. One way to achieve this is by using the harvest index (the ratio of yield to total biomass) to estimate the harvested portion from total productivity. Another more complex method is to use crop models to estimate yield given the remotely sensed leaf area index estimates over the growing season (Lobell 2013).

**Crop residue productivity**

For sustainable intensification, the productivity of the land needs to be assessed in terms of all that is produced (not just grain yield). This is especially important where residues are used for fodder or returned to the soil.

Residue production

Crop residues can be weighed at harvest from a known area or the amount can be estimated by farmers for a measured land area. If the residue biomass is not measured but grain yield is measured, then the residue biomass can be estimated from the harvest index for the variety of the crop. The harvest index is simply the portion of all biomass that is harvested as grain.

The quality of crop residues is important to assess (e.g. digestibility and nutrients) when its primary use is as animal feed. Near-infrared spectroscopy can be used to determine the amount of crude protein and the digestibility of the residues. If residues are incorporated into the soil then it may be useful to analyze the amount of nitrogen and other plant nutrients. The ratio of carbon to nitrogen in the residues is an important factor in the rate of decomposition, which determines when the nutrients are likely to be available for the plants. The C:N ratio can be estimated through look-up tables. Nutrient values of tropical species have been developed through the Organic Resource Database (Palm et al., 2001).

Net Primary Productivity

As with yield, the crop residue biomass can be estimated through remote sensing of net primary productivity as the non-grain portion of net primary productivity, usually inferred by the harvest index.

**Animal productivity**

Animal productivity must be broken down into all the parts of the animal that are used (including manure). Estimating the land area used for grazing or fodder production is likely to be difficult or imprecise. Where draft power is the primary “product” then an assessment of the condition of the draft animals before, during and after their peak season of use may be needed.

**Variability of productivity**

Yield variability can be easily interpreted as a percent of total production. It could also be used to estimate the probability of falling below food self-sufficiency or of achieving a production target (e.g. break-even point for a cash crop). Variability across time and across space measure different aspects of variability and cannot be substituted for each other.

**Input use efficiency**

The concept of efficiency focuses on avoiding or reducing wastage of a resource. Input efficiency is supposed to increase the performance of the system and minimize losses to the environment; for example, if excess fertilizer use like nitrogen ends up in rivers or is emitted as harmful gases. Finding avenues to ensure efficient use of applied nitrogen to the soils by the plant will be critical to avoid wastage and losses. Examining input use efficiency (e.g. kg grain/kg nitrogen input per season; kg grain/liter of irrigation water per season, etc.) depends on the goal of the project and the biophysical, social, and economic context (Dobermann, 2007; Fixen et al., 2015). Input use efficiency is especially important to measure where a specific input is limiting (such as water in some contexts).

It is important to note that input use efficiency should not be used by itself as an indicator but should be used along with yields. Reasons for this are that input use efficiency is often highest at low yields. Farmers are striving to increase yields --- not just input use efficiency.

**Yield Gap**

Yield gap estimates are important to determine how close or far yields from a field or farm are to an attainable yield for that particular soil and climate. It also facilitates comparisons across agro-ecological zones by converting productivity information into the ratio of actual production to the highest observed production in similar conditions or from yield potential maps. There are limitations to inferences that can be made from this due to strong assumptions about the feasibility of reaching the highest yield but adjustment factors have been used to reduce this error (Lobell et al., 2009). For crops, yield potential is calculated as the difference between actual yield in the farmer’s field and the potential yield, or water limited yield, or maximum locally attainable yield from farmers in the area. Methods for data collection to assess yield gap include: crop model simulations, maximum farmers yield based on surveys, yield contest, and field experiments (Lobell et al., 2009; Van Ittersum et al. 2012)

**Cropping Intensity**

Cropping intensity is defined as the number of crops a farmer grows in a given agricultural year on the same field (Raut et al., 2011) and is another means for intensification of production from the same plot of land. Cropping intensity is likely to be important to monitor where the intervention affects the likelihood of irrigation or planting during short season rains.

# 8. Economic Domain (Note: The superscript letters (a,b,c) after each metric refer to the measurement methods in the right-hand column)

| ECONOMIC DOMAIN | | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| Indicator | Field/plot level metrics | Farm level metrics | Household level metrics | Landscape + | Measurement Method |
| Profitability | Net income a ($/crop/ha/season) | Net income a,c (summation of net income across crop and livestock activities) | Net income a,c (summation of net income across crop and livestock activities) | Contribution to regional or national GDP b | a Survey  b Regional and national statistics  c Participatory evaluation |
| Variability of profitability | Coefficient of variability of net income a  Probability of low profitability a,b | Coefficient of variability of net income a  Probability of low profitability a,b | Coefficient of variability of net income a  Probability of low profitability a,b |  | a Survey  b Farmer evaluation |
| Income diversification | N/A | Diversification index a | Diversification index a |  | a Survey |
| Returns to land, labor and inputs | Net returns a (monetary value of output/input used) | Net returns a (monetary value of output/input used) | Net returns a (monetary value of output/input) |  | a Survey and productivity measurements |
| Input use intensity | Input per ha a | Input per ha a | Input per ha a |  | a Survey |
| Labor requirement | Labor requirement (hours/ha) a,b  Farmer rating of labor c | Labor requirement (hours/ha) a,b  Farmer rating of labor c | Labor requirement (hours/ha) a,b  Farmer rating of labor c |  | a Recall survey  b Direct observation  c Farmer evaluation |
| Poverty | N/A | N/A | Asset index a  Per capita hh expenditure a  Wealth categorization b |  | a Survey  b Participatory exercise |
| Market participation | N/A | N/A | % production sold a | Total sales a | a Survey |
| Market orientation | N/A | N/A | % land in cash crops a  Market orientation index a |  | a Survey |

**Description of Economic indicators**

**Profitability**

Profitability measures the viability of the agricultural business using data from its revenue and expenses. This could be done for a single season or agricultural year, or over multiple years of agricultural investment. The single year assessment (accounting profits) is a good evaluation of the agricultural investment (in this case a technology) in the short term. However, examining long-term profitability (economic profits) over multiple years is important where long-term investments (like machinery, buildings, and irrigation equipment etc.) are involved. A “business”, which agriculture is, may survive one year of losses, but multiple years of losses jeopardize the business (Hofstrand, 2009). There are a number of profitability indicators used that include; net income, gross returns, and returns to capital and labor. For long-term economic evaluation of technologies, performance measures such as net present value, benefit cost ratio, and internal rate of returns are commonly used.

Net Income

An indicator of profitability is net income that is derived from incomes and costs of production. When considering the decision to adopt a technology, a farmer examines whether there are additional net gains from the technology or innovation (for brevity innovation and technology will be used interchangeably). Costs of production includes variable costs of production such as labor, fertilizers, seed, feed costs etc. plus non-cash expenses that might include annual depreciation of equipment such as a tractor. Depreciation is added to the net income calculation because for long term profitability, the farmer must be able to replace the equipment once it wears out. In addition, interest paid on loans for the business should be added to the expenses (costs).

A positive net income is a sign of a profitable business and one can assess two technologies by looking at their relative profitability. The higher the net income, the more profitable. In addition, this net income measure can be used to assess what economists refer to as returns to factors of production such as labor, capital and management (see Engle, 2012). A ‘gross margin’ indicator has been used in literature as a profitability measure where net income cannot be calculated. In some cases, data on costs of production such as labor, farm implements, water management structure, etc. may not be available or collected to ‘net out’ all the costs of production from agricultural income. Therefore, the gross margin may be presented as a close estimate to the net income. It is also important that the scientist note what costs they have not accounted for in the calculation of net income.

**Variability of profitability**

Variability in profit is an important metric because it provides a measure of variation from the mean (average) that can be attributed from either the production or consumption side. From the production side (see productivity domain) it may be due to variation in amount produced while on the consumption side, it might be due to the demand (price changes) for the output that might affect the price offered. This metric provides information about variation across space and time that is useful for policy makers to ascertain how the population is performing. If there is a large variation in the profitability within the population and/or through time then a technology may be too risky, even if average net incomes are positive.

**Income diversification**

Income diversification[[1]](#footnote-1) within and among farming households is important in examining how shocks and agricultural stresses may impact household welfare. In addition, sub-indicators of this index provide an indication of the contribution of a specific innovation or source on total household income and coping strategies.

**Returns to labor and capital**

Returns to labor is related to profitability of the resource “labor”. This metrics enables one to assess the opportunity cost of the resource. For example, if it is more profitable for a household head to work off-farm for a going wage rate of $5 per day and his returns to labor on his own farm is $3, it might be better for him to work off-farm (assuming that there are opportunities for such off-farm work). This measure may be computed from data collected above to compute the profitability indicator. This analysis may be done both for labor and capital. It should be important to note that ascertaining the rate of return to a resource and comparing it with a new technology is important for this analysis. Wage rate for agricultural labor may be computed from hired wage data from the agricultural survey but wage rate in alternative wage jobs might be difficult to come back in rural agrarian societies.

**Input use intensity**

Input use intensity measures the amount of a given input used per unit of area (e.g. kg nitrogen input / ha; liter of irrigation water/ha, etc.). Input intensity provides a measure of assessing two important issues; 1) whether a given input is used and 2) amount used per unit area. This indicator may also provide an indication of the community’s use of the input and to assess the need to supply more in cases where low levels are used or, in case of overuse, explore options to advise farmers about how to reduce the amounts used or use the resource more efficiently. This might include information on diminishing marginal returns and yield plateaus with input use.

**Labor requirement**

Labor is major factor of production in developing agrarian communities with low rate of mechanization. Examining the labor requirements for growing a given crop and the impact of a new technology on labor demand and supply is essential to ensure that there is enough labor available in the season for crop production or to note if there is inequity in gender allocation or needs for labor for a new technology. Labor use is assessed across the growing season. Data are collected on total labor days or hours that a farmer allocates to production of a given crop. It is important to note that labor demands may vary over the season and by activity depending on demand and supply of labor at that given time. For example, during the planting season, households with large farms may demand more labor and household than smaller farms while smaller farms may have excess labor to supply to the market at that time, hence covering the excess demand. Labor is also often gender-specific so the data should be disaggregated by sex when possible.

**Poverty**

Poverty is estimated as a welfare measure to ascertain the minimum level of income what is adequate to sustain a livelihood.

Poverty rate (Per capita household expenditure)

An international poverty line is set by the World Bank and is used to calculate the number of persons that fall below or above this measures. Poverty indicators include; 1) head count ratio – percentage of people below the poverty line, 2) poverty gap – estimates the ‘depth’ of poverty, and 3) and measure of income inequality among the poor- “gini index” (Foster, Greer, and Thorberke, 1984). Poverty (or income) is usually estimated in developing countries by using consumption expenditures to obtain a wealth status of a given household rather than use of income (Deaton, 1997). The value of consumption expenditure by the household on food and non-food items of the household is divided by the number of household members to obtain a per capita measure of consumption expenditure.

Asset index

An asset index is a poverty measure used to categorize household’s wellbeing and wealth ranking using data from their ownership of asset. In cases where consumption and expenditure data is not available, the asset index is often used (Filmer and Pritchett 2001; May and Carter 2001; Carter and Barrett 2006). This approach is argued to be a better measure than consumption or income since it is more stable over time (Carter and Barrett, 2006; Michelson et al., 2013).

Wealth categorization

Wealth categorization is a commonly used participatory exercise where key informants develop categories of wealth or well-being and then rank or group the households in their community. For example, key informants may choose three categories such as “poor”, “intermediate” and “rich”. Wealth is a relative category therefore research scientists should be aware that members in the communities possess knowledge of the wealth positions of community members. The adoption and adaption of an intervention may differ by wealth categories because of the different endowment in resources or productive assets. Using this wealth ranking approach may be an important alternative and complement to other methods such as conventional surveys that estimate poverty rates and asset based wealth indices - and may be cheaper to administer.

**Market Participation**

Market participation examines whether a farmer sells their agricultural commodities or buy inputs from the market. For this metric, we focus on the sale of output to the market. In some cases, farmers may have access to the market but not participate in the market. We are more concerned with who participates. Those household that do not sell agricultural produce to the market are non-participants and for those who participate in the market, this indicator could also be used to examine the extent of participation. This may look at the amount of produce that is sold.

Data on market participation is collected by survey. The basic data collected are on the amount produced by farmers and then the quantity of that production that is sold. A binary measure can be computed for each farmer to determine whether or not they participated in the market. If quantity sold is greater than zero, then there is participation. In some cases, the researcher would like to know about the extent of participation. This may be either expressed as a proportion (percentage of harvest that is sold) or an absolute amount (number of kilograms of harvest sold).

**Market Orientation**

Market orientation is defined as production with an intention to sell to the market. Market orientation examines the agricultural production by the household that is destined for the market. This indicator is used to distinguish between market participation of the household (indicator described above) versus degree of commercialization. Market orientation has a focus on cash crops since production of these (traditional cash crops) was geared towards the market; but this measure can also be used for non-traditional cash crops. For example, with changes in market demand and prices, other food items may be classified as cash crops depending on how much is being sold to the market by the producer.

Market orientation indices have examined the proportion of household production sold to the market and the proportion of land allocated to marketable crops of total cultivated land by the household (Gebremedhin and Jaleta, 2010; Hichaambwa and Jayne; 2012). The calculation of the percentage of land allocated to cash crops is a straight forward metric. The data on land allocated to cash crops is collected from the agricultural management survey at the field scale. The unit of analysis is the proportion of total land cultivated that is allocated to cash crop(s). The scientists need to specify which crops are considered cash crops for that given context. A pre-defined metric needs to be set to categorize cash crops for the context of study. For example; is one considering only traditional cash crops (like coffee, cotton, tea, etc.) or crops for which the household sells a high percentage of output to the market (for example one may say if farmer sales above X% of produce to the market, then that is a cash crop for this context).

9. Environment Domain **Part 1: Biodiversity and water** (The superscript letters (a,b,c) after each metric refer to the methods in the right-hand column)

| ENVIRONMENT DOMAIN (Part 1: Biodiversity and water) | | | | | |
| --- | --- | --- | --- | --- | --- |
| Indicator | Field/plot level metrics | Farm level metrics | Household level metrics | Community/Landscape + metrics | Measurement method |
| Vegetative Cover | % Vegetative cover by type (tree, shrub, grass, invasive) a,b  % Burned land a,b  % Bare land a,b | % Vegetative cover by type a,b  % Burned land a,b | N/A | % Vegetative cover by type c  % Burned land c  % Bare land c | a Quadrats, transects or visual estimate of cover  b Participatory exercise  c Satellite images |
| Plant Biodiversity | Alpha Diversity Index a,b  # species or varieties a,b | Beta Diversity Index a,b  # species or varieties a,b | N/A | Gamma Diversity Index a,b  % Natural habitat c | a Vegetation sample  b Transects  c Satellite images |
| Pest levels | Weed abundance and severity a,b  Parasitic weed levels a,b  # pest insects by type a,b  Presence of invasive species a,b |  |  |  | a  Seasonal transects  b Traps |
| Insect Biodiversity | # pollinators a,b,c  Diversity index a,b,c  # beneficial insects a,b,c |  |  | # pollinators a,b,c  Diversity index a,b,c  # beneficial insects a,b, | a Traps  b Direct observation  c Seasonal transects |
| Fuel (energy) Security | Fuel biomass (e.g. wood, residues) produced on plot a,b,c | Fuel biomass (e.g. wood, residues) produced on farm a,b,c | % of hh fuel by type (wood, charcoal) a,b  # mo.s energy security a,b  Time necessary to collect fuel a  % household fuel from farm a | % of fuel from off-farm a,b  Spatial arrangement of fuel sources b  % of HHs with energy security a | a Survey  b Participatory exercise  c Biomass measurement |
| Water availability | Soil moisture a,b,c  % of plants wilting b,d  Infiltration rate a,d | Irrigation use b  % of fields wilting b | Water sufficiency b  Water security index b  Water security rating d | % of irrigated land b, e  % of stream flow not diverted f  % hh with sufficient water b | a Field and lab tests  b Survey  c Crop models  d Participatory exercise  e Remote sensing  f Stream sampling |
| Water quality |  |  | Rating of water quality b | % water sources with clean water a,b  % population with clean water supply b  Salinity a  Phosphate (mg/L) a  Nitrate concentration (mg/L) a  Pathogenic microbe concentration - #/ml a | a Water sampling  b Household survey |

**9. Environment domain part 2: Soil and pollution** (Note: The superscript letters (a,b,c) after each metric refer to the methods in the right-hand column)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| ENVIRONMENT DOMAIN (Part 2: Soil and pollution) | | | | | | |
| Indicator | **Field/plot level metrics** | **Farm level metrics** | **Household metrics** | **Community/Landscape + metrics** | **Measurement method** |
| Erosion | Erosion (tons/ha/yr) a,b,c  Rating of erosion d |  | N/A | Sediment load (mg/L) e  Erosion (tons/ha/yr) b | a Direct measurement  b Models  c Survey  d Participatory exercise  e Stream sampling |
| Soil carbon | Labile carbon (POXC) a  Total carbon (Mg/ha) a  Partial carbon budget b,c |  | N/A | N/A | a Soil test  b Survey  c Measurements |
| Soil acidity | Soil pH (acidity) a  % Aluminum saturation a |  | N/A | N/A | a Soil test |
| Soil salinity | Electrical conductivity a |  | N/A | N/A | a Soil tests |
| Soil nutrients | Soil nutrient levels a  Nutrient partial balance b  Biological nitrogen fixation a | Nutrient partial balance b  Biological nitrogen fixation a | N/A | Nutrient partial balance a,b | a Soil tests  b Survey andlookup tables |
| Soil physical quality | Aggregate stability a  Bulk density a  Water holding capacity a  Infiltration rate a |  |  |  | a Field and lab tests |
| GHG Emissions | CO2 equivalent emitted per hectare a | CO2 equivalent emitted per hectare a | N/A | CO2 equivalent emitted per hectare a | a Lookup tables by activity or input |
| Pesticide use | Active ingredient applied per ha a | Active ingredient applied per ha a | N/A | Pesticides concentration in water b | a Agricultural survey  b Water tests |

**Vegetative Cover**

Vegetative cover is important for both soil protection from the elements and also provides biomass for livestock feed and household and human consumption. This indicator is presented as a percentage of area that is covered by vegetation which may be in natural landscapes or agricultural areas – crops, canopy cover, and other vegetation. Generally, the percent cover and percent tree cover are inclusive of each level despite needing slightly different metrics between farm and field. They are inclusive of both perennials and non-perennials. The estimates need to be made at periods of peak and minimum vegetative cover (e.g., rainy and dry seasons).

**Plant Biodiversity**

Biodiversity is an important indicator in sustainability of agricultural systems. Biodiversity can be examined in terms of the plant species and has focused on the number of species in a sample (richness) and the distribution of species with in the sample (evenness). Two commonly used indicators are the Shannon-Weaver index and Simpson index (Simpson, 1949; Shannon and Weaver, 1949). Examining species richness and evenness enable researchers to assess extinction of natural species in addition to suitability of a habitat for a given species. As scales increase, species diversity is of greater concern. There are two main indices of alpha diversity: the Simpson index (which is more sensitive to changes in richness) and the Shannon index (which is a better measure of dominance in terms of abundance). Choosing between the two depends on the goals and context. Often both are reported. Detecting covariances in yields by crop can be helpful for evaluating how much diversification helps mitigate climate risk – one would expect sorghum and millet to vary together with rainfall so they do not provide functional diversity.

**Insect biodiversity**

This indicator focuses on number of species of pollinators and other beneficial insects plus the richness of these species (evenness and abundance). Pollinators in agriculture play an important role of fertilization of key crops critical for food production and cash crops. There are also many beneficial insects that are predators or parasites of insects that are pests for crop production. When these beneficial insects are missing, or have very low populations, pest insect populations can grow exponentially, resulting in either higher pesticide application or lower yields. A reduction in the number of species may have a significant effect on productivity. One way to assess the number of species and type is to trap them and examine the type of species. In order to assess diversity of the species two indices are used in the literature - the Simpson index (which is more sensitive to changes in richness) and the Shannon index (which is a better measure of dominance in terms of abundance). Choosing between the two depends on the goals and context.

**Fuel**

Fuel is very important for livelihood in developing agricultural landscapes. In many cases in rural areas, biomass energy is the dominant form of fuel and includes wood, charcoal, crop residues, manure. Agricultural lands and wooded or forested areas are a major source of biomass for fuel and ensuring that consumption does not out-weigh the supply is key to ensure sustainability of this source. In addition to biomass, animal manure is also a critical source in regions where livestock plays and important role in livelihoods. Apart from access to these types of fuel, assessing the cost of this fuel to the household and benefits from conserving access to it is critical.

**Water Availability**

Water availability indicator assess if there is sufficient water for both plant growth and human consumption. At the field level, the indicator examines the presence of adequate moisture in the growing season and also excess water that would be detrimental to plant growth. Water availability at the farm level examines the presence and source of water for irrigation of land during times of moisture stress whereas at the household level, water availability examines the months of water insecurity, the source of adequate and available clean water for human and livestock consumption.

**Water Quality**

Water quality indicators are meant to provide information on the fit for use of water for crop, livestock, and human consumption. Efficient management of livestock and crops can minimize contamination of water but also access to ‘usable water sources’ or technologies that increase the quality of water for use. This indicator looks at nitrate levels, phosphate levels, zoonotic contaminations, and salinity levels.

Partial nutrient balances may serve as a proxy and indicate if there is excessive use of nutrients that pose as a hazard for leaching and contamination of water sources.

**Soil Erosion**

Soil erosion examines movement of soil and may lead to soil degradation. Soil erosion or soil loss may be estimated qualitatively by assessing slopes, presences of soil conservation structures, looking for bare soil, rills or gullies, exposed rock or roots, or quantitatively by collecting, weighing and analyzing eroded sediments from a field or farm, or indirect measurements that examine sediments in streams or rivers adjacent to agricultural landscapes. Other measurements include use of erosion pins that may provide an indication of the amount of soil eroded over time from the baseline marked point on the pin at which it was set to ground level. Because direct measurement can be expensive and erosion measurement may take time to be examined and linked to a given erosion cause, other predictive measures of erosion are used. The universal soil loss equation is used to examine the amount of erosion that may occur from sheet or rill erosion but not gully (Wischmeier and Smith, 1960).

**Soil Carbon**

Soil carbon is a critical indicator of soil quality that is important for soil moisture and nutrient retention and livelihood of soil microbes (Doran and Jones, 1996; Reeves, 1997; McBride et al, 2011). Soil carbon content is calculated by obtaining soil samples, preparing it for lab analysis and calculating the percentage of soil carbon in that sample. It is necessary to measure bulk density along with percentage soil C if the total amount of soil carbon per area is to be determined, and this poses methodological challenges. The heterogeneity of soil C, and large volume relative to the small changes over time further complicate measurement and assessment of change over time. It is not necessarily the total soil carbon that is important for soil quality, but may be more related to carbon loss relative to saturation potential (Hassink et al., 1997; Palm et al., 2005). Soil active carbon is a smaller pool than total soil C, and the various means of assessing this active soil C pool are often influenced by management over shorter time periods, in a detectable manner. Thus metrics of active soil C such as permanganate oxidizable carbon and CO2 mineralization can be measured on soil samples that are used to measure total soil organic C, and the ratio, or active C measurements alone, these are indicators of sustainability. For example, management has been shown to influence POXC and CO2 mineralization over time, and these indicators have been shown to be related to processed soil C (that contributes to soil C sequestration), as well as nitrogen fertilizer efficiency, and crop yield (Culman et al., 2012; 2013; Moebius-Clune et al., 2011).

**Soil Acidity**

Acidity of the soil affects crop growth through constraints to root growth. Exchangeable aluminum Al3+ concentrations are measured using soil samples to examine the toxicity from aluminum. A percentage Al saturation greater than 60% (if pH <5.5) may be used as a critical value for assessment for many crops – though some are more tolerant to soil acidity – coffee, tea, sweet potato, cassava.

**Nutrient Partial Balance**

Partial nutrient balance is a useful and parsimonious indicator that examines nutrient output per unit of nutrient input (output minus input to the soil). A commonly useful interpretation is that a value closer to 1 implies that soil fertility will be maintained at a steady state (Fixen et al., 2015). At the farm fields one of the main focus has been the amount of N,P,K, added to the fields versus that is removed by crops– but the analysis of nutrient extracted can be extended to micro soil nutrients and even carbon if needed. Studies and projects are introducing measure to use fuzzy logic to indicate the value where; 1) partial nutrient balance is ‘stable’, 2) improving or in excess supply, and 3) worsening.

**Green House Gas Emissions**

Agriculture is a major GHG emitter and therefore has implication on climate change (IPCC, 2007; Vermeulen et al., 2012). The main source include fertilizer use that leads to nitrous oxide emissions from the soil and manures, methane emissions from ruminants and rice production, and land use change (IPCC, 2014; Gustafson et al., 2015). Nitrous oxide emissions are of major concern with agriculture contributing 85% of the total anthropogenic emissions (IPCC, 2007b). Quantifying emissions at the plot and field level require direct and indirect measurements. In situations where no information is available and costs of measuring emissions are high, nitrous oxide emissions are measured as a percentage of nitrogen applied. The IPCC uses a tier 1 approach where a 1% of added N[[2]](#footnote-2) is emitted as N2O (IPCC, 2007b); but this measure has its limitations. Studies have shown a non-linear N2O fluxes as N use increases, where once N amount needed (uptake) by the crops is met, there is a significant increase in gaseous N losses (Robertson et al; 2001; Kim and Hernandez\_ramirez, 2010; Grace et al., 2011). A number of studies have used a measure of N2O emissions per unit of grain produced (yield scaled emissions or intensity of emissions). Using yield scaled emissions provides a good measure to link productivity to environmental impact (Venterea et al., 2010).

**Pesticide Use**

Pesticide indicators focus on the risk and environmental impact of pesticides on water quality and death of species. In as much as pesticides have negative impacts, their benefits should be noted that include improving productivity through protection from crop losses, vector control that reduces diseases, and indirect impacts like increased food security and nutrition. On the cost side, pesticides are dangerous to the targeted and non-targeted species and when used in excess amounts may kill other plant, insect, and animal species affecting bio-diversity and other ecosystems services. Indicators that examine impacts may enable reduction of negative effects of it use.

**10. Human Condition Domain** (Note: The superscript letters (a,b,c) after each metric refer to the methods in the right-hand column)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| HUMAN CONDITION DOMAIN | | | | | |
| Indicator | **Field/plot level metrics** | **Farm level metrics** | **Household level metrics** | **Community/Landscape + metrics** | **Measurement method** |
| Nutrition | Protein production (g / ha) a,b  Micronutrient production (g / ha) a,b | Total protein production (g / ha) a,b  Total micronutrient production (g / ha) a,b  Availability of diverse food crops a | Access to nutritious foods a  Dietary diversity a  Food consumption score a  Nutritional status (underweight, stunting, wasting) c  Uptake of essential nutrients d | Market or landscape supply of diverse food e,f  Dietary Diversity a  Rate of underweight, stunting and wasting c  Average birthweight c | a Survey  b Look up tables  c Anthropometric measurements  d Blood tests  e Survey of marketed foods  f Participatory mapping |
| Food security | Food production (Calories/ ha) a,b | Food production (Calories/ ha) a,b | Food availability a  Food accessibility a  Food utilization a  Food security composite index a  Months of food insecurity a  Rating of food security c | Total food production a  % population food secure | a Survey  b Look up tables  c Participatory assessment |
| Food Safety |  |  | Mycotoxins (toxicity units per gram) a  Pesticide contamination a,b  Post-harvest losses c |  | a Chemical testing  b Health center data  c Survey |
| Human health |  |  |  | Incidence of zoonotic diseases a  Incidence of vector borne diseases a | a Health center data |
| Capacity to experiment |  |  | # of new practices being tested a,b | % of farmers experimenting a,b | a Individual survey  b Focus group discussion |

**Description of Human Condition Indicators**

**Nutrition**

Nutrition is both an output and input for sustainable agriculture. The choice of what food to produce, market, and consume have a direct effect on nutritional outcomes. Good nutrition plays an important role in achieving the optimal childhood development and supply adults with proper nutrition to be productive individuals (UNSCN, 2015). Production and consumption of nutritious food may alleviate the burden of under nutrition, overweight, and micronutrient malnutrition at the household and individual level (IFPRI, 2014) that are key components of sustainable development. Dietary indicators focus mainly on women and young children who are the most vulnerable groups to malnutrition. A more common measure of nutrition in the household is the use of anthropometric measurements[[3]](#footnote-3). A survey instrument focusing on children under the age of 5 within the household and the mother of the children or a female in charge of food preparation. This survey may provide an indication of level of stunting, underweight, overweight, and body mass index of a given household and population. From the data collected, critical values on the standard deviations for the Z-scores is used to obtain the percentage of overweight, underweight, stunted and wasting population. A software from the world health organization can be downloaded that generates weight-for-age, height-for-age, weight-for-height z-scores (<http://www.who.int/childgrowth/software/en/> ) This a popular method to examine nutrition status of a population but may be limited by cost due to the required sample size that might be needed to obtain reliable estimates at a landscape of community level.

Micro-nutrient production;

This indicator is important in areas or populations where there is a nutrient deficiency and the particular technology that is being assessed will increase nutrient supply. For nutrient supply estimates, look-up tables of nutrient concentrations of different crops and foods have been used to estimate consumption. The tables have been developed by the Food and Agricultural Organization (FAO) (<http://www.fao.org/infoods/infoods/tables-and-databases/en/> ) and Harvard University’s School pf Public Health (2016) (<https://www.hsph.harvard.edu/nutritionsource/food-tables/> ). This indicator is estimated at the field scale and some additional indicators such as nutrient yields are used to assess relative supply across technologies and regions (De Fries et al. 2016).

Nutrition Awareness

Nutrition awareness is used to indicate the percentage of population that have received information on how to improve their production, preparation, and consumption of nutritious foods. This information on nutritional awareness may be collected through a survey or a rough estimation of population that was reached through radio programs or flyers that were given out during a nutrition campaign.

Production of nutritious food does not necessarily lead to improved nutritional outcomes. There are many assumptions along the way: Availability of diverse foods 🡪 Equitable Access (at markets)🡪 Uptake of nutrients (level of disease and health e.g. suffering from worms or aflatoxins then can’t take in nutrients). Diet diversity surveys require careful training of enumerators to avoid introducing biases into the data.

**Food Safety**

Food safety is a key issue that ensures both a fit for consumption and quality of the food. Mycotoxins are often cited as potential issue that affects food safety and may lead to chronic illness if excessive mycotoxins exist in a given product (Milicevic et al., 2010). Mycotoxins can be produced due to weather conditions during the growing season or poor storage. Post-harvest losses due to toxicity occur at a number of levels that include, during harvesting, post-harvest handling and storage, processing and distribution, and during preparation and consumption. The most common measure of post-harvest loss is through questionnaire where household is asked whether they incurred any post-harvest loss; the cause of the loss, and what proportion of the harvest was lost (Kamiski and Christiaensen, 2014). Pesticide contamination is an issue that also requires additional attention in food seafety and quality.

**Food Security**

Measuring food security has been a challenge but the concept has been defined as a state in which “all people at all times have the both the physical and economic access to sufficient food to meet their dietary needs for a productive and healthy life” (USAID, 1992). Food security has evolved from food availability to examining nutritional capabilities of the food that is produced or accessible to a household (Burchi and De Muro, 2016). With the development of the Sustainable Development Goals, there has been a challenge to examine agriculture, nutrition, and food security in an integrated manner (UNSCN, 2015). The Food and Agricultural Organization has defined three main pillars of food security as food availability, food access, and food utilization.

Food availability

Food availability is defined as the availability of sufficient quantities of food of appropriate quality that is supplied through domestic production or importation. Food availability indicator measures the amount of food produced by the household, amount that is sold and purchased per capita to come up with an estimate of calories and nutrients available per capita (Remans et al. 2013). In addition, this measure may also include a subjective food availability index that may be based on household report on the number of months or days of food insecurity. At the field level, scientist may use an alternative approach to estimate the potential calories would be available to the household at a given production level. This may be done by estimation the total calories and nutrients produced and using participatory approaches to infer how the farmer might use this crop or livestock output.

Food access

Food access may be defined as the ability to acquire sufficient quality and quantity of food to meet the nutritional requirements of individuals within the household for a productive life (Swindale and Bilisky, 2006). Food access indicator tends to focus on the economic aspect and examines the ability of household or person to purchase food. These indicators also include a computation of the household percentage of total expenditure allocate to food and may also compute the minimum cost of a nutritious diet for the household to examine if household income or expenditure may be able to achieve this minimum diet. This indicator is computed at the household level because the data on consumption expenditure is computed for the household and then disaggregated to a per capita level using the household composition (members in the household).

Food Utilization

Food utilization refers to the individual’s capacity to make use of food for a productive life ((Swindale and Bilisky, 2006). Food utilization focuses on the diversity of the food consumed in the households examining the food groups, calories consumed from staples versus non-staples and also an evaluation of protein and micro nutrient composition of food. We have yet to fully explore all of the relevant food security index tools. For example, there is a FANTA tool for FS assessment, FAO also has one; Coates et al 2007 (Household food insecurity assessment scale). Food affordability can be categorized by staples and non-staples. For details see Drewnowski (2010).

Month of Food Insecurity

Month of food security is an indicator used to assess the frequency of household food insecurity and is the months in which these incidents occurs. This can be used as a quick measure of whether or not household do face food insecurity by asking a few questions. The food insecurity questions are found in most multi-indicator surveys such as the LSMS and are used as a subjective measure of food insecurity.

**Human health**

Human health may be at risk due interaction with animals or through vector borne diseases that affect both animals and humans. For example, chicken production in close proximity to the household member may increase the risk of Newcastle disease virus; which can be transmitted to humans. There are also other livestock diseases that can be transferred to humans in addition to other contamination from fecal matter. Campylobacter bacteria from animal feces may be taken by humans through contaminated food and may attack the humans small and large intestines causing chronic illness. In some cases, this contamination has been associated with stunting in children.

**Capacity to experiment**

Capacity to experiment is ability of the household to use a new technology. This may be assessed depending on the number of components that household or farmer is able to incorporate. A score may be provided for those who are able to use a component for a new intervention and those who do not use one. This indicator though in it’s infancy of description, might be used ex-ant by collecting data on household resource endowment to obtain a prediction on which household might not have the ability to experiment. This later example may work in the absence of subsidized products, but where subsidized or free technology is provided, then observing and collecting data on usage might provide an indication on adopters and non-adopters.

# 11. Social Domain: (Note: The superscript letters (a,b,c) after each metric refer to the methods in the right-hand column)

| SOCIAL DOMAIN | | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| Indicator | Field | Farm | Household level metrics | Community/Landscape + metrics | Measurement method |
| Gender equity | N/A | N/A | Resources: Land access by gender a-d  Livestock ownership by gender a-d  Capacity: Access to information a-d  Agency: Time allocation by gender a-d  Management control by gender a-d  Market participation by gender a-d  Achievements: Income by gender a-d  Nutrition/Food security by gender a-d  Health status by gender a-d  Cross cutting: Rating of technologies by gender b | Women Empowerment in Agriculture Index a, d | a Individual survey  b Participatory evaluation  c Focus group discussions  d Household survey |
| Equity (generally) | N/A | N/A | Access to resources (land and livestock ownership) a-d  Agency (leadership roles) a-d  Achievements (income, nutrition, food security, health, well-being) a-d  Rating of technologies by group a-d | Variability and distributions resources, agency, and achievements a-d | a Key informant interviewKey informant interview  b Participatory evaluation  c Focus group discussions  d Household survey |
| Social cohesion | N/A | N/A | Participation in community activities a,b,c  Level and reliability of social support a,b,c  Family cohesion a,b,c | Social groups c  Participation in social groups a,b,c  Incidence of social support a,b,c | a Household survey  b Focus group discussions  c Key informant interviews |
| Collective action | N/A | N/A | Participation in a collective action group a | Collective action groups a,b  Capacity of groups a,b  Incidence of conflicts related to collective action a,b  Effectiveness of conflict resolution measures a,b | a Household survey  b Key informant interviews |

**Description of social Indicators:**

**Gender equity**

Drawing from the gender empowerment literature we developed a conceptual framework for gender equity in agriculture that is detailed in Appendix 2. Following the Hemminger et al. (2014) we use the empowerment framework from Kabeer (1999) to categorize gender equity metrics as follows:

* Resources – these metrics measure differential access to resources for agriculture
* Agency – these metrics measure differential levels of control over resources
* Achievements – these metrics measure gendered differences in realizing various benefits from agriculture

Most of the gender equity metrics require obtaining information from men and women and the calculating the gender gap. For easy interpretation, we follow the suggestion by Rao et al. (2016) to compute the gender gap as the ratio of the female value to the male value expressed as a percentage.

Ideally these metrics would be carried out using data from all adults in a household. However, interviewing multiple respondents in a household is resource intensive. In some situations, it may be possible for one respondent to provide information about who in the household owns and controls various resources. While this information is collected at the individual or household level it will often be useful to analyze it at the community level. In many cases, it may be useful to disaggregate the average gender gap for various categories of women (household heads or part of a dual-headed household, junior or senior women in the household, etc.).

Land access by gender

This metric compares the average area of land used solely or jointly by women compared to the average area of land used solely or jointly by men. Due to the complexity of intrahousehold labor allocation it is not possible to assume that those who work the land have decision-making power about the benefits from their labor. Therefore, we suggest using the ability to decide how to use the harvest (sale or consumption) as a feasible metric for access to that land.

Where possible, land quality should be taken into consideration. For example, farmers’ subjective assessment of soil fertility could be used to analyze the differences in quality of land that men and women have access to. The monetary value of the land would also show land quality but accurately quantifying the market value for land is only possible where land markets are well developed.

Following Rao et al. (2016) we distinguish between control over the produce and control over the income from the produce, which is addressed later. It is relatively simple in a household survey to add the question “Who is responsible for deciding what to do with the harvest?” for each field, where multiple household members can be selected. Joint responsibility of a field should not be interpreted automatically as equality and will need to be interpreted in the local context. Qualitative questions that could be useful for a deeper understanding of gendered responsibility include:

* In this community, which fields are typically the responsibility of the man? Which fields are the responsibility of the woman? Why?
* When someone says that they decide how to manage the harvest jointly as a household, what does that look like? How equal is the decision-making?

Livestock ownership by gender

Livestock ownership can either be separated by type of livestock (cattle, small ruminants, poultry, etc.) or combined using Tropical Livestock Units (Jahnke 1982). In many agricultural surveys the respondents are asked the number of all types of livestock. This could easily be followed up by a question “Who is the owner of these livestock?” for each type. Asking about the monetary value for each type of livestock if it were sold could also allow for combining livestock across categories.

Time allocation by gender

This metric can be used to assess gender equity through the quantitative measurement of differences in time spent on various tasks. While the division of labor by gender is not inherently negative, it is possible to assess gender equity by comparing amounts of leisure time for each gender or comparing time spent on the least desirable or most taxing tasks. Also, this information can be combined with other metrics in the agency and resource categories to assess who benefits from how the time is spent. Rao et al. (2016) recommend the following metrics gender labor inequities: “Average hours of leisure for women and for men or proportions of women and men who report inadequate leisure time”

Depending on the technology being assessed it may be useful to develop detailed time allocation for activities directly or indirectly affected by that technology. In general, one can partition labor analyses into three broad categories – agricultural tasks (including livestock care), non-agricultural income generating tasks, household chores and leisure time. Agricultural tasks for crops may best be asked for each field for a given season after the harvest. Other tasks may be better asked for an “average” day. More details can be found on this in the “labor requirement” indicator in the economic domain.

Management control by gender

This metric aims to capture differences in decision-making power between men and women. To be operationalized it will be necessary to choose the most important decision in the given context.

For cropping systems one could measure the amount of land where women report being the primary decision-maker about crop management (solely as well as jointly) compared to the amount of land where men report being the primary decision-maker (solely as well as jointly). Some simple survey questions are “Who decides what crop to plant?”, “Who decides what inputs to apply?” and “Who decides when to plant, fertilize or weed?”. Agency over the use of production factors (such as plowing) can be measured indirectly (such as by when women’s and men’s fields get prepared).

A longer-term focus for cropping systems may be helpful where SI technologies aim to improve land quality. Ownership of land shows that the individual has the incentives to invest in the long-term. However, quantifying ownership of land by gender is not a simple matter for two reasons. First, ownership of land may mean different things in different contexts. Complete ownership would include having the right to manage it, the right to control the benefits from it, and the right to transfer rights to others (Rao et al. 2016). In many developing country contexts, traditional tenure systems do not give individuals the rights to transfer land and ownership refers simply to the rights to manage and to control benefits from it. Second, quantifying ownership is difficult because de facto ownership may be different from de jure ownership (the name on the title). Rao (2016) justifies a focus on de facto rights by giving the example of someone officially owning distant land that they are not able to access while another has access to land without a title. These de facto rights to land need to be assessed at the individual level and not simply at the household.

Management control gender gaps need to be explored for other areas of agriculture as well, such as livestock raising, irrigation schemes and collective marketing efforts.

Market participation by gender

Within a household this could be a comparison of who markets which products. At the landscape+ scale the incidence of men and women participating in the market could be compared.

Income by gender

Income is both a resource for and an achievement from women’s empowerment. When considering it as a resource the focus is on access to finances. and can be measured by asking who participates in the decisions to buy items such as agricultural inputs or daily goods. When considering income as an achievement it can be measured based on net income from crops or animals controlled by each gender. If detailed time allocation has been collected, then returns to labor can be calculated and compared across genders.

Nutrition, food security and health by gender

These metrics simply use disaggregated data from the human condition domain to compare achievements across gender.

Ratings of Technologies by gender

Technologies that are used at the farm and field scale may be evaluated differently by men and women. The data collection happens at the household scale so the gendered rating is listed at the household level.

Women Empowerment in Agriculture Index

This index is calculated by following a specific data collection methodology where male and female responses are compared. This survey process may be too demanding for many programs but it does provide a great deal of information about the various facets of empowerment at the community or regional scale.

**Equity (generally)**

This indicator draws on the conceptual framework detailed in appendix 2 and has many similarities to the gender equity indicators described above. Often there may be a reason to focus on equity concerns across specific groups such as by livelihood strategy (crop growers, livestock herders, fishermen) or by ethnicity. In other cases, the focus may be on comparing how the technology performs across wealth and age groups. Usually these comparisons can be done across households which reduces much of the complexity from intrahousehold decision-making that is essential for gender equity analysis.

**Social Cohesion**

Direct indicators of social cohesion are “membership rates of organizations and civic participation” and “levels of trust” (in other people), while proxies are income distribution and ethnic heterogeneity (Easterly et al. 2006). Social cohesion is seen as society level issue while social capital is micro-level focused. Grootaert et al 2004 have developed a guide for Measuring Social Capital with household surveys.

**Collective action**

Collective action is common in many areas for managing natural resources (such as irrigation, water, fisheries). Collective action can also refer to cooperative efforts in agriculture for marketing, processing, procuring inputs, etc. Collective action can be affected by changes in the community if that change alters incentives or affects trust levels.

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# Appendix 1: Exercise on tradeoffs and synergies for sustainable agricultural intensification

Sustainability is inherently multi-dimensional. For this exercise, sustainable agricultural intensification is evaluated across five domains: productivity, economic, environmental, human condition, and social. Frequently, progress towards sustainability is complicated by tradeoffs (negative interactions) or enhanced by synergies (positive interactions) across these dimensions. For example, an increase in crop production through the use of excessive levels of fertilizers and pesticides may be economically profitable but result in reduced water quality, increased greenhouse gas emissions, and potential human exposure to toxic pesticides. On the other hand, the addition of fertilizers on nutrient depleted soils may increase crop production and the amount of crop residues added to the soil, resulting in increased soil carbon levels and other associated soil health indicators.

This exercise aims to facilitate the identification of context-specific tradeoffs and synergies related to sustainable agricultural intensification. Researchers, development agencies, and implementation partners may use this exercise to analyze systematically the tradeoffs and synergies associated with the technologies or interventions that they focus on and to identify possible alternative interventions with fewer tradeoffs or higher synergies.

1. Preparation (5 min)

The last page of this document is a worksheet that includes the five domains: productivity, environment, economic, human condition and social, and lists of many of the indicators within those domains. The indicators are written in a general way but you may need to make them more specific for your purposes and to explicit interventions.

Print the worksheet and have a pencil and eraser ready. Start by writing a brief summary of the research focus or development project that you want to consider for this exercise. Identify one or two of the indicators on the worksheet that are at the center of your project. Circle these indicators.

Next, choose a specific context where your project operates (e.g. a village or district) to focus the exercise. Write a brief description of the farming system in that context (crops grown, population density, market access, livestock integration, soils and climate, etc.). Also indicate at which scale your project is working directly (field, farm, household, landscape/administrative unit) and also with which other scales that research is likely to have broader scale impacts.

Discuss the current (baseline) situation as it relates to the five sustainability domains. Then discuss a scenario (or project objective) and what that project intends to do for the different domains.

2. Draw linkages (10 min)

Start with the baseline (current) situation: Draw arrows between the indicators you have circled and the ones that relate to it. Some limits are needed here, because almost everything could be related to everything else somehow. To avoid confusion try limiting yourself to at most 10 arrows that seem to be the most important in the context you are thinking of. For each arrow indicate if it is a positive (synergistic) relationship (using a plus sign) or if there is a negative tradeoff relationship (using a negative sign). You can use one plus, two pluses, or three pluses to show the strength of the synergy and the same for minus signs on tradeoffs. You can also write the word DELAY on the arrow if there is a significant time lapse between the cause and the effect.

Remember that you may need to adjust the indicators for your specific context. If your work focuses on one crop you may want to split productivity into the crop you focus on and other important crops that are related to its production. Similarly, you may want to split out livestock productivity by livestock product. In some contexts, it may be important to split out social and human condition concepts by livelihood strategy (e.g. pastoralists vs. settled farmers).

Then go through the scenario (using a new diagram to may make it easier): If farmers change from their current practice to use the technology being researched or promoted, what concepts might be affected? Look at the arrows and the signs and note how they would change compared to the baseline.

3. Analysis

A first step in analyzing the linkages you developed is to reflect on if you have captured the most important concepts that would be affected by your project through the arrows you drew.

Are there any indicators that may need to be added to the diagram?

Were all of the domains connected by your arrows? If not, does that seem appropriate? (It is possible that some interventions will not have direct or large effects in all domains)

Another simple step for analyzing your work is to share it with a colleague. By explaining the linkages you identified and getting the reaction of someone familiar with your project, you may be able to refine it further.

Diagram the two situations (baseline and scenario) onto spidergrams on another worksheet. Spidergrams are a good way of comparing alternatives agricultural practices or strategies and how they affect the different domains of sustainability. The arms of the spidergram each represent an indicator. The origin or center of the diagram can be zero and the arms at the end represents 100%, or the ideal situation or target. Estimate how close each of the indicators is to 100% for the baseline and scenario.

Consider the following as you construct the spidergrams of the tradeoffs and synergies you have identified:

* How could each tradeoff be mitigated through the implementation of your project?
* Are there indicators that you could monitor over your project’s implementation to make sure potential tradeoffs are adequately being mitigated?
* How could synergies be maximized and leveraged so that the benefits are greatest?
* Are there additional indicators that you can identify and measure to definitively demonstrate these synergies or tradeoffs?

If you want to analyze the dynamics of these tradeoffs and synergies further you can use Fuzzy Cognitive Mapping, for example by re-creating your worksheet using the Mental Modeler free software ([www.mentalmodeler.org](http://www.mentalmodeler.org)). By doing so you can easily run scenarios for how concepts may be affected if one or more concepts increased or decreased. The software also provides basic metrics about the network of relationships you have drawn.

**Economic**

Profitability

Variability of profitability

Income diversification

Returns to land, labor and inputs

Input use intensity

Labor requirement

Poverty

Market participation

Market orientation

**Human condition**

Nutrition

Food security

Food safety

Human health

Capacity to experiment

**Environment**

Vegetative cover

Plant biodiversity

Pest levels

Insect biodiversity

Fuel security

Water availability

Water quality

Erosion

Soil carbon

Soil nutrients

Soil acidity

Soil salinity

Soil physical quality

Greenhouse gas emissions

Pesticide use

**Productivity**

Crop production

Residue production

Animal production

Variability in production

Input use efficiency

Yield gap

Cropping intensity

Draw arrows for connections --------------->

Use +, ++, or +++ to show synergies

Use -, -- , or --- to show tradeoffs

**Social**

Gender equity

Equity (age, marginalized groups)

Social cohesion

Collective action

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Focus: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Example baseline diagram for Enset (false banana) in Ethiopia – notice the negative effect on gender equity due to high female labor requirements in processing

**Project Name:** SIIL Intensification Ethiopia

**Research focus, objective, and scale:** \_Improve Enset management practices and productivity at the household scale **(Baseline)**

-

++++

**Economic**

Profitability

Variability of profitability

Income diversification

Input use efficiency

Limitations to land, labor and capital

Poverty rates

Market participation

Market orientation

Draw arrows for connections --------------->

Use +, ++, or +++ to show synergies

Use -, -- , or --- to show tradeoffs

**Environment**

Vegetative cover

Plant biodiversity

Fuel availability

Water availability

Water quality

Soil erosion

Soil carbon

Soil acidity

Soil salinity

Nutrient partial balance

Greenhouse gas emissions

Pesticide use

delay

++

+

+

-

**Social**

Gender equity

Age equity

Equity of marginalized groups

Level of social cohesion

Level of collective action

Conflicts over resources

Prestige in community

**Productivity**

Yield

Fodder production

Animal productivity

Cropping intensity

Variability in production

**Human condition**

Nutrition

Food safety

Food security

Human health

Capacity to experiment

Example diagram of intended changes from Enset intervention – mechanization to reduce female labor, agronomics to improve production and market linkages to improve profits.

**Project Name:** SIIL Intensification Ethiopia

**Research focus, objective, and scale:** \_Improve Enset management practices and productivity at the household scale (**Scenario)**

+

++++

**Economic**

Profitability

Variability of profitability

Income diversification

Input use efficiency

Limitations to land, labor and capital

Poverty rates

Market participation

Market orientation

Draw arrows for connections --------------->

Use +, ++, or +++ to show synergies

Use -, -- , or --- to show tradeoffs

**Environment**

Vegetative cover

Plant biodiversity

Fuel availability

Water availability

Water quality

Soil erosion

Soil carbon

Soil acidity

Soil salinity

Nutrient partial balance

Greenhouse gas emissions

Pesticide use

++

+

delay

++

+

+

-

**Social**

Gender equity

Age equity

Equity of marginalized groups

Level of social cohesion

Level of collective action

Conflicts over resources

Prestige in community

**Productivity**

Yield

Fodder production

Animal productivity

Cropping intensity

Variability in production

**Human condition**

Nutritional status

Nutrition awareness

Food security

Capacity to experiment

Human health

**Appendix 2:** Conceptual framework for equity indicators

This conceptual model divides the possible gender/youth/ethnic equality indicators into four major groups.

1. The first group describes the access to resources. Indicators for the most important of these resources or practices could be collected in a survey disaggregated by group (men and women). For gender analysis it can be difficult to assess intra-household access to household resources but subjective responses may suffice (E.g. On what proportion of your land could you independently decide how to manage…?).
2. The second group focuses on awareness of information related to SI practices. Much of the focus may be on familiarity with production practices but there should also be sufficient attention to information that relates to how the increased production is utilized – marketing, storing, processing. Some information about this could be generated based on records of who is participating in field days, trainings, etc.
3. The third group of concepts relate to agency or decision-making power. There are several domains of the Women’s Empowerment in Agriculture Index (WEAI) that focus on these concepts. The WEAI tool is designed to compare average responses for men and women and it includes question regarding their decision making (such as regarding production decisions, the ownership or sale of assets, control over income, and time allocation). Similar questions could be developed for youth or for minority ethnic groups. While it may be difficult to measure decision-making power, the results of decisions can be directly observed (actual time allocation, actual market participation, etc.).
4. The fourth group of concepts are the achievements or outcomes from the combination of agency, resources and information. Gaps in productivity, health, income and food security are the focus. For gender analysis, it can be difficult to determine productivity gaps when plots are jointly managed.

Finally, these concepts and how they interact are conditioned by the structures (norms, policies, and laws) and relationships in a particular context.

**Figure A2:** Conceptual framework for empowerment and equality in agriculture – adapted from (Hemminger et al., 2014) (based on Kabeer, 1999) including elements from CARE gender toolkit and WEAI.

*Achievements*

* Yields
* Health
* Food security
* Nutrition
* Income
* Subjective well-being

*Agency*

* Decision-making power
* Strategies and skills for negotiating relationships
* Time allocation
* Mobility
* Market access

*Structures:* Norms, policies, laws

*Information awareness*

* Production practices
* Market opportunities
* Post-harvest skills
* Value addition skills

*Access to resources*

* Land
* Finances
* Equipment
* Labor
* Purchased inputs

*Relationships:* Household, community, kin, political

1. Income diversification is not synonymous with livelihood diversification [↑](#footnote-ref-1)
2. After water availability, N availability is the most limiting factor to plant growth for non-leguminous crops (Van Groenigen et al., 2010). [↑](#footnote-ref-2)
3. Anthropometric measures are only suggested for large scale development projects with sufficient time and sample size to detect this [↑](#footnote-ref-3)